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# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

ACCELERATION MEASUREMENTS DURING LANDING IN ROUGH WATER

OF A  $\frac{1}{7}$ -SIZE DYNAMIC MODEL OF GRUMMAN XJR2F-1

AMPHIBIAN - Langley Tank Model 212

TED NO. NACA 2378

By

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## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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## ACCELERATION MEASUREMENTS DURING LANDING IN ROUGH WATER

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## SUMMARY

Tests of a  $\frac{1}{7}$ -size model of the Grumman XJR2F-1 amphibian were made in Langley tank no. 1 to examine the landing behavior in rough water and to measure the normal and angular accelerations experienced by the model during these landings.

All landings were made normal to the direction of wave advance, a condition assumed to produce the greatest accelerations. Wave heights of 4.4 and 8.0 inches (2.5 and 4.7 ft, full size) were used in the tests and the wave lengths were varied between 10 and 50 feet (70 and 350 ft, full size). Maximum normal accelerations of about 6.5g were obtained in 4.4-inch waves and 8.5g were obtained in 8.0-inch waves. A maximum angular acceleration corresponding to 16 radians per second per second, full size, was obtained in the higher waves. The data indicate that the airplane will experience its greatest accelerations when landing in waves of about 20 feet (140 ft, full size) in length.

## INTRODUCTION

The Grumman XJR2F-1 amphibian is a twin-engine high-wing airplane with a design gross load of 22,600 pounds, a power loading of 7.9 pounds per horsepower, and a wing loading of 27.2 pounds per square foot. This airplane is intended for use by the Navy as

a utility transport and for air-sea rescue work, and therefore must be seaworthy and structurally satisfactory for rough-water take-offs and landing. Tests of a  $\frac{1}{7}$ -size powered dynamic model of the

Grumman XJR2F-1 amphibian were made in Langley tank no. 1 to determine the landing behavior in rough water and to measure the normal and angular acceleration experienced by the model during these landings. The model was landed into oncoming waves 4.4 and 8.0 inches high with lengths of waves from 10 to 50 feet. These tests provide the designer with experimental data for comparison with theoretical water load calculations.

#### MODEL AND INSTRUMENTATION

The model used for the tests was a  $\frac{1}{7}$ -size dynamically similar model with powered propellers. A detailed description of the model is given in reference 1; important dimensions are given in table I.

The model was fixed in yaw and roll but had freedom in the plane of symmetry (trim  $-5^\circ$  to  $20^\circ$ , rise 14 in., and fore and aft motion, 11 in.). Two linear accelerometers were mounted within the model. One was located on the axis of rotation (the center of gravity) and oriented to respond to accelerations normal to the keel. A second accelerometer was mounted 1 foot aft of the center of gravity and also responded to accelerations normal to the keel. For each landing, time histories of the motions of the model with respect to the carriage, the passage of wave crests, the speed of the carriage, and the accelerations were recorded. Angular accelerations were calculated from the linear accelerations obtained with the two accelerometers. The test setup, which is shown in figure 1, is described in detail in reference 2. The trim is the angle between the forebody keel at the step and the horizontal.

#### TEST PROCEDURE

The test procedure was, in general, similar to that described in reference 2. The towing carriage was accelerated to a speed such that the model was airborne; the model was trimmed to approximately the desired landing trim by use of the elevators; and the carriage was then decelerated at a rate of two feet per second per second, thus the model was allowed to land. Sufficient propeller thrust was used so that the resultant horizontal force was approximately

zero at contact with the water. The model remained free to move fore and aft throughout most of the landing run in which high impact accelerations occurred.

All of the landings were made with the model approaching oncoming waves in a direction perpendicular to their crests. No attempt was made to have the initial landing contact occur on a predetermined part of a wave. At least five landings, however, were made for each condition of waves to obtain initial contacts at several parts of the wave. All of the landings were made with a model gross load of 65.2 pounds (22,600 lb. full size), the center of gravity located at 25 percent mean aerodynamic chord, and with slotted-type flaps deflected 45°.

#### DISCUSSION

Records of the time histories of two landings are reproduced in figures 2 and 3. In taking data from the records only accelerations corresponding to impacts with the water were considered. The large accelerations that occurred after the model was thrown clear of the water were caused by contact with a rise stop. In general the motion in waves was violent, the model was thrown clear of the water several times for each landing. The average number of impacts in which the model bounced clear of the water for each landing are plotted against wave length in figure 4. The records showed that the most severe impact occurred subsequent to the initial impact of the landing and at speeds between 70 and 90 percent of the minimum flying speed.

Most landings were made at landing trims ranging from 4° to 12°. Examination of the data obtained in this test and in previous tests, such as reported in reference 2, indicates that landing trim is not a principal factor governing the magnitude of the maximum impact accelerations, since the maximum accelerations generally occur at some wave encounter subsequent to initial impact. In this test, maximum change in trim during a single wave encounter showed no consistent variation with respect to wave length. The model usually attained maximum trims between 15° and 20° after bouncing clear of the water at speeds below the stall. The maximum change in trim that occurred during any one wave encounter varied from about 15° to 25°.

The maximum vertical acceleration is plotted against wave length in figure 5, for wave heights of 4.4 and 8.0 inches. Tests in 8.0-inch waves were not made for wave lengths less than  $17\frac{1}{2}$  feet since the waves at these short lengths became erratic (see reference 2).

The maximum vertical acceleration occurred at a wave length of approximately 20 feet (140 ft, full size) or three times the length of the hull. The maximum values of vertical acceleration obtained were 6.5g in the 4.4-inch waves and 8.5g in the 8.0-inch waves. However, the most probable accelerations to be encountered in the 4.4-inch and 8.0-inch waves are about 4.0g and 6.0g, respectively. The large variation of normal acceleration experienced when several landings were made at the same wave heights and lengths can be attributed principally to the fact that it was not feasible to pre-determine on what parts of the waves the model would contact during landing.

The greatest angular acceleration obtained during these tests was approximately 110 radians per second per second (16 radians/sec/sec, full size) in the 8.0-inch waves. This maximum acceleration occurred in the shortest wave length investigated. Failure of the instruments prevented obtaining similar data for the 4.4-inch waves.

The Grumman engineering staff has made a more detailed and specific analysis of the landing records obtained during this investigation and has used these experimental data to check their theoretical load calculations (reference 3).

#### CONCLUSIONS

Rough-water landings of a  $\frac{1}{7}$ -size dynamic model of the Grumman XJR2F-1 amphibian disclosed the following characteristics:

1. The model encountered maximum accelerations when landing in waves of about 20 feet (140 ft, full size) in length. The most severe impact occurred subsequent to the initial impact of the landing and at a speed between 70 and 90 percent of the minimum flying speed.
2. The maximum values of normal acceleration encountered by the model were 6.5g in 4.4-inch waves (2.5 ft, full size), and 8.5g in the 8.0-inch waves (4.7 ft, full size). However, the most probable accelerations to be encountered in 4.4-inch and 8.0-inch waves are about 4g and 6g, respectively.
3. The maximum angular acceleration encountered in the 8.0-inch waves was about 110 radians per second per second (16 radians/sec/sec, full size). The maximum change in trim that occurred during landing for any single wave encounter varied between  $15^\circ$  and  $25^\circ$ .

4. Maximum trims between 15° and 20° were attained when the model was thrown clear of the water during landings in waves.

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## REFERENCES

1. Land, Norman S., and Zeck, Howard: Tank Tests of a  $\frac{1}{7}$ -Size Powered Dynamic Model of the Grumman XJR2F-1 Amphibian. Spray Characteristics, Take-Off and Landing Stability in Smooth Water - Langley Tank Model 212 TED No. NACA 2378. NACA RM No. L6J10, Bur. Aero., 1946.
2. Benson, James M., Havens, Robert F., and Woodward, David R.: Landing Characteristics in Waves of Three Dynamic Models of Flying Boats. NACA RM No. L6L13, 1946.
3. Scott, Walter H., Jr., and Skurla, G. M.: Rough Water Landing Tests of a  $1/7$  Scale Dynamically Similar Model of the XJR2F-1 Airplane. Rep. No. E-53, Grumman Aircraft Eng. Corp., June 25, 1946.

TABLE I  
PRINCIPAL DIMENSIONS OF GRUMMAN XJR2F-1 AMPHIBIAN

Item	NACA model 212 (1/7 size)	Grumman XJR2F-1 (full size)
<b>Hull:</b>		
Beam, maximum, in. . . . .	13.58	95.0
Length of forebody, in. . . . .	44.57	312.0
Length of afterbody, in. . . . .	36.00	252.0
Length of tail extension, in. . .	23.15	167.0
Length over all, in. . . . .	103.72	731.0
Length-beam ratio . . . . .	5.92	5.92
Type of step . . . . .	Transverse	Transverse
Depth of step at keel, in. . . . .	0.97	6.8
Depth of step at keel, percent beam . . . . .	7.1	7.1
Angle of dead rise at step, deg.		
Excluding chine flare . . . . .	22.5	22.5
Including chine flare . . . . .	19.5	19.5
Angle of forebody keel, deg . . .	0	0
Angle of afterbody keel, deg . . .	6.5	6.5
Angle of sternpost to base line deg . . . . .	8.0	8.0
Angle of forebody chine flare at step, deg . . . . .	-10.0	-10.0
Area of ventilation ducts, sq in. . . . .	3.16	155.0
<b>Wing:</b>		
Area, sq ft . . . . .	16.8	822.0
Span, in. . . . .	137.14	960.0
Angle of incidence at root, deg	5.0	5.0
Mean aerodynamic chord (M.A.C.)		
Length, in. . . . .	18.42	129.1
Leading edge forward of step, in. . . . .	9.04	63.3
Leading edge above base line, in. . . . .	19.20	134.4
<b>Horizontal tail surface:</b>		
Area, sq ft . . . . .	3.47	170.0
Span, in. . . . .	49.72	348.0
Angle of stabilizer to wing chord, deg . . . . .	<sup>a</sup> -0.5	-1.5
<b>Propellers:</b>		
Diameter, in. . . . .	<sup>a</sup> 19.5	133.0
Clearance above keel line, in. . .	<sup>a</sup> 12.6	86.5

<sup>a</sup>Not scale value of full size.

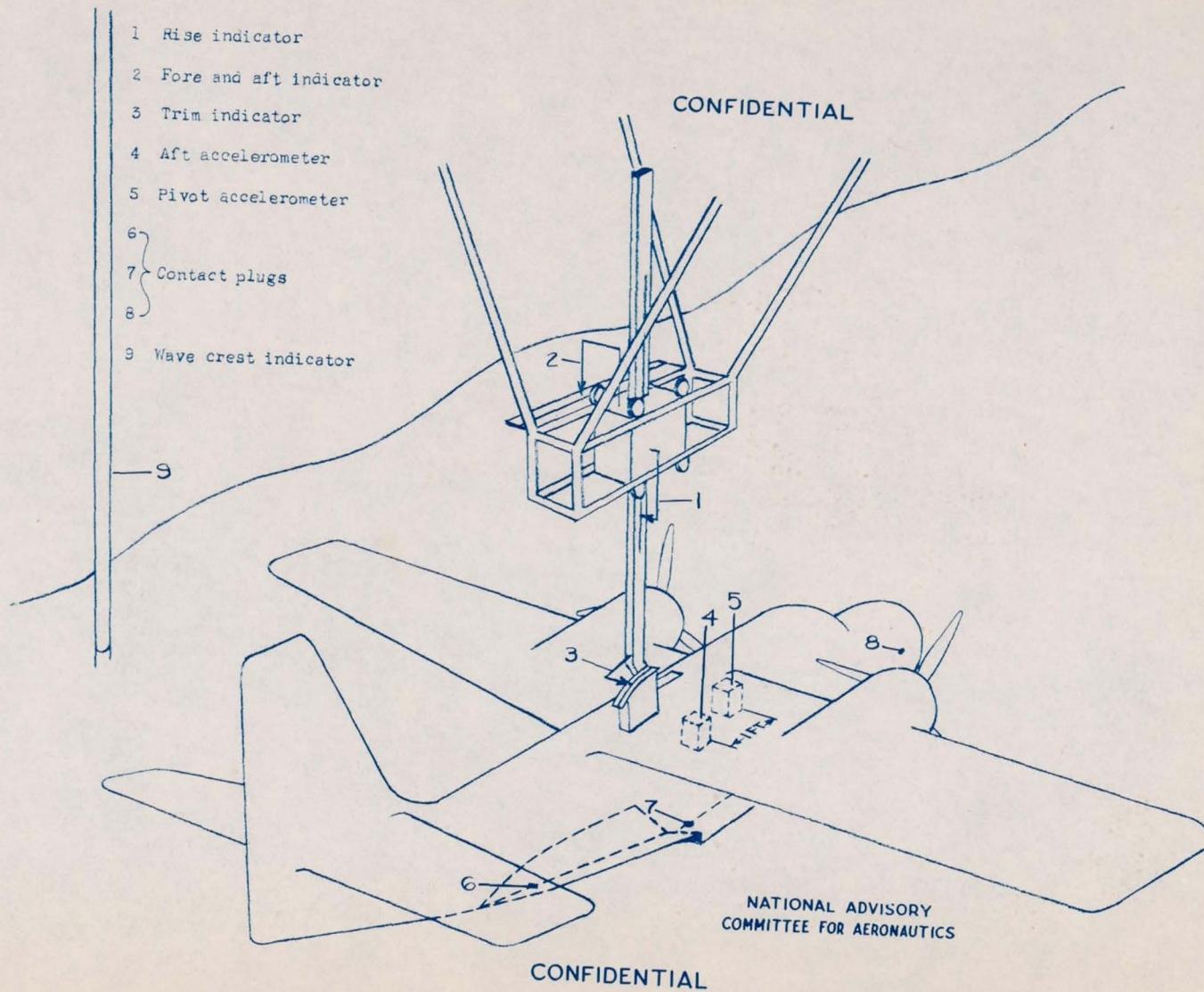


Figure 1.- Sketch of model and towing gear setup.

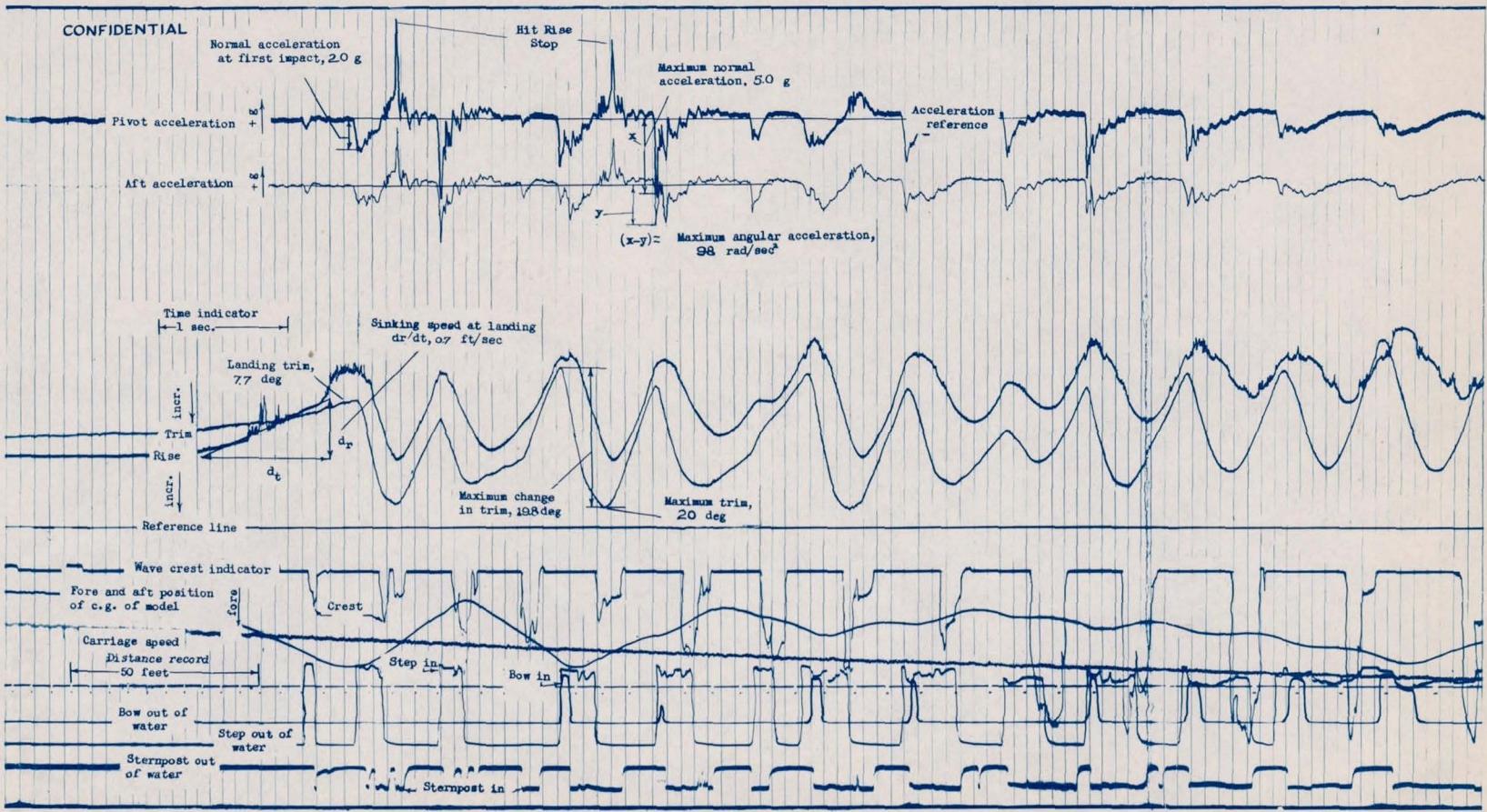
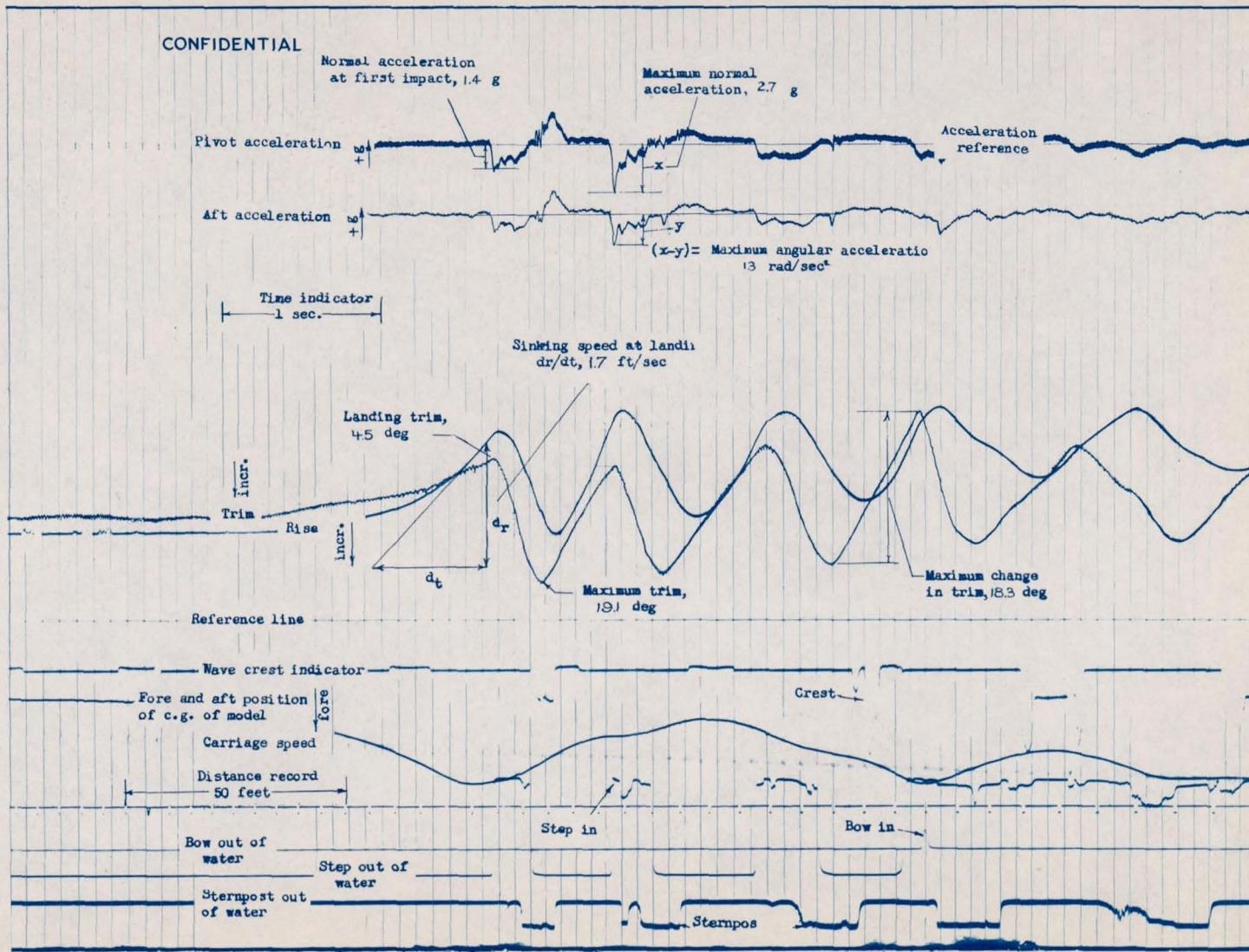


Figure 2 . - Model 212. Typical rough water time history landing record. Wave height 80, inches; wave length 22, feet.

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**CONFIDENTIAL** Figure 3 . - Model 212. Typical rough water time history landing record. Wave height 8.0, inches; wave length 48 , feet.

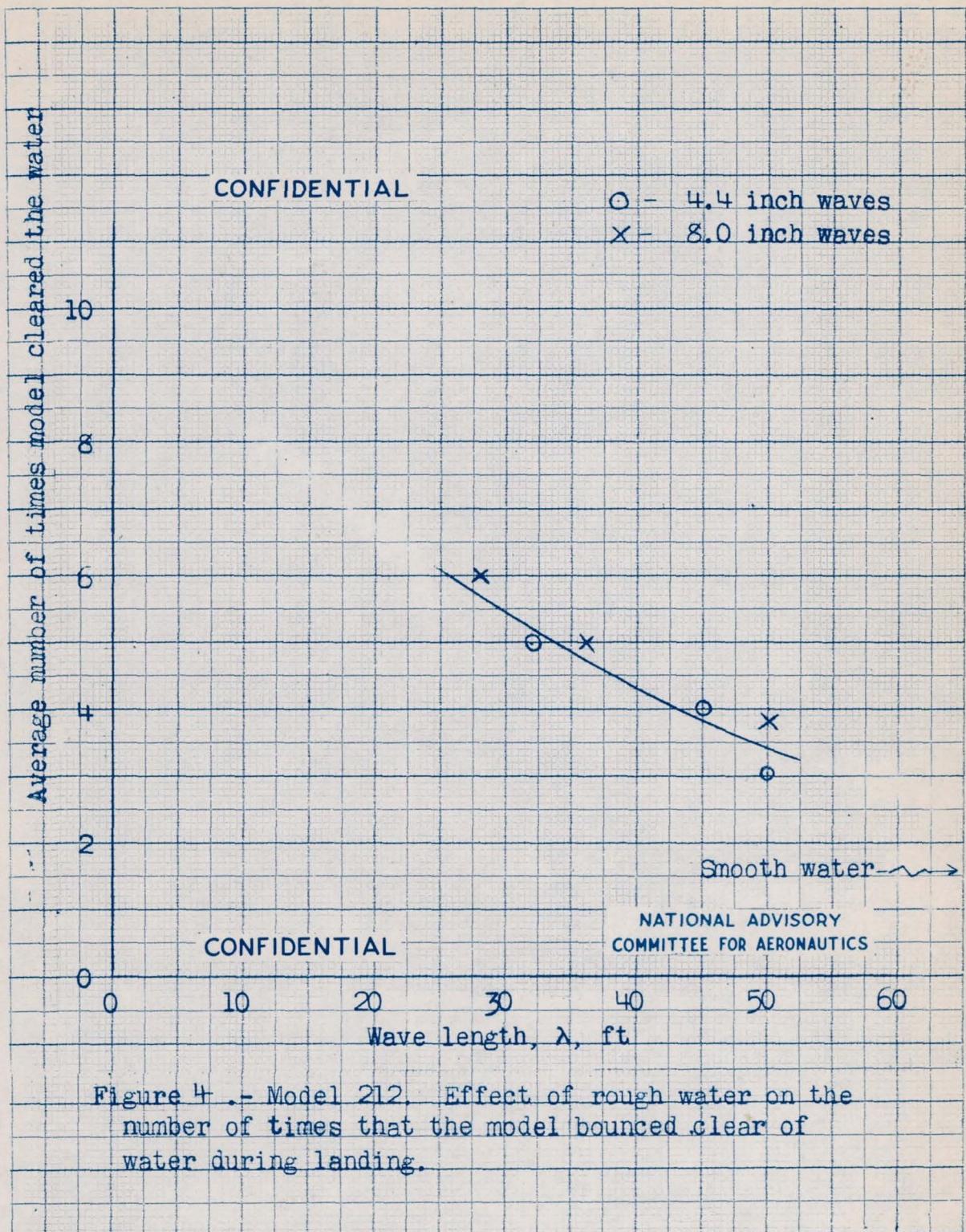
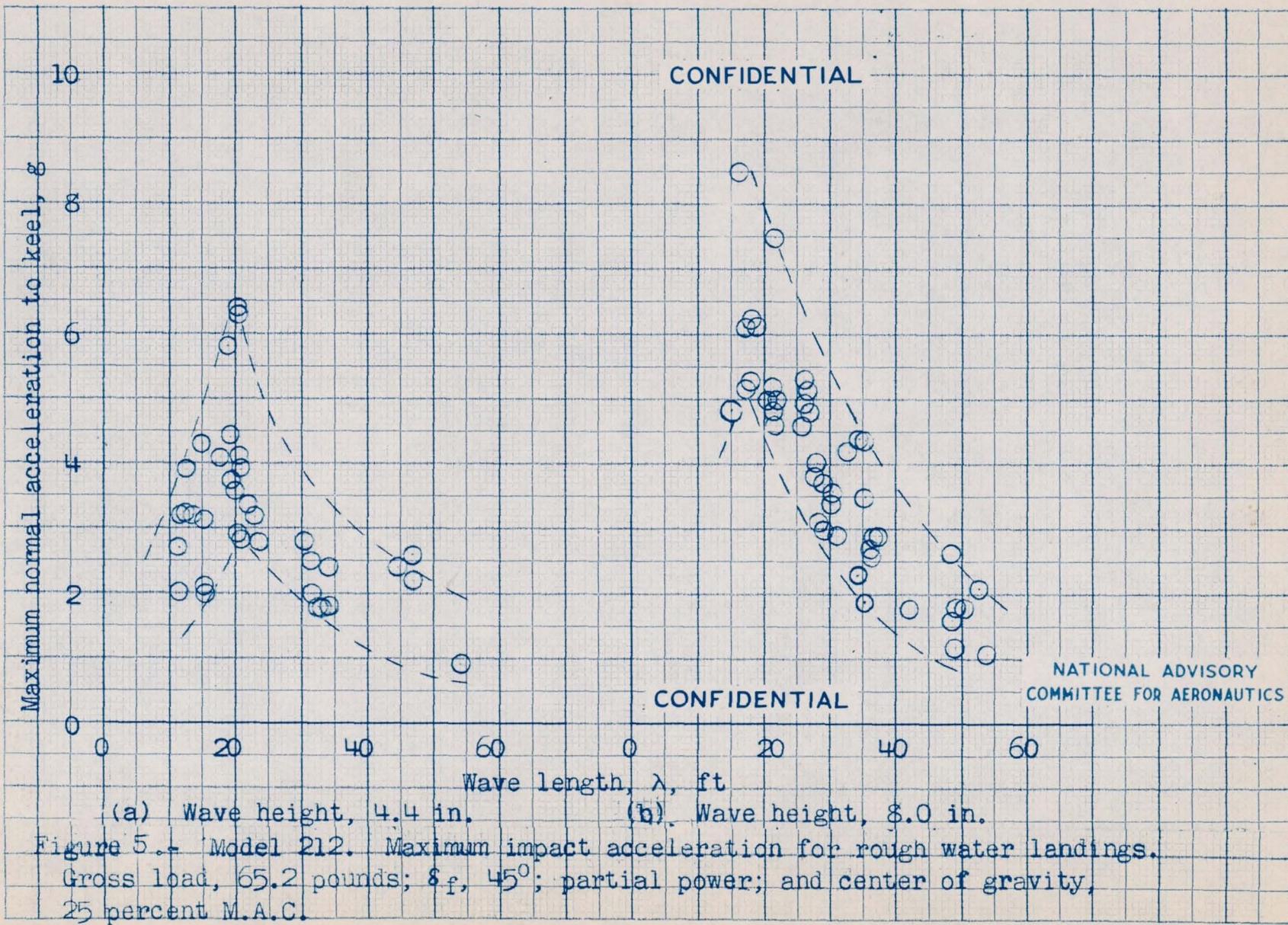


Figure 4 .- Model 212. Effect of rough water on the number of times that the model bounced clear of water during landing.



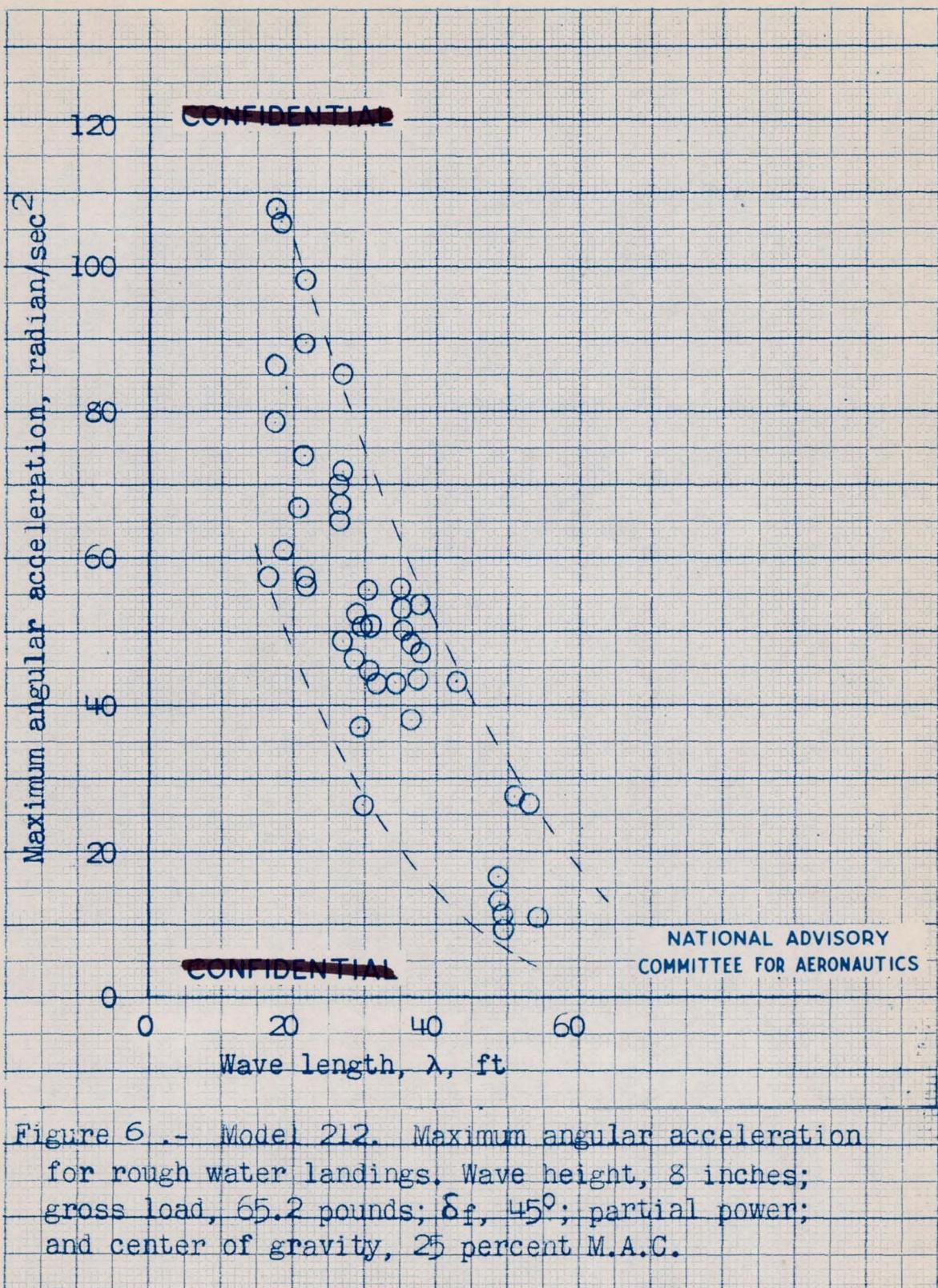


Figure 6 .- Model 212. Maximum angular acceleration for rough water landings. Wave height, 8 inches; gross load, 65.2 pounds;  $\delta_f$ ,  $45^\circ$ ; partial power; and center of gravity, 25 percent M.A.C.